GRL GOBLE RAUSCHE LIKINS AND ASSOCIATES, INC.

SPECIALIZING IN DYNAMIC MEASUREMENTS AND ANALYSES

10:00

December 6, 1990

Traylor Brothers, Inc.
911 Western Avenue
Seattle, Washington 98104

Attention: Mr. Brad Palmer

Re: Coleman Dock, Seattle Washington
Piles R2.1, S2.1, T2.1, T4.4 and CC7.1 GRL Job No. 906016

Dear Brad:

On November 27 and 30, 1990 GRL conducted tests with the Pile Integrity Tester™ (P.I.T.) and the Pile Driving Analyzer™ (PDA) at the Coleman Dock. This letter presents results from all tests, including a CAPWAP analysis for Pile R2.1. Prior PDA and P.I.T. results were reported in earlier submittals from GRL, including our reports dated March 30 and November 7, 1990 which also included soil information for the site.

TEST DETAILS

Piles

Piles R2.1, S2.1, and T2.1 were 16.5 inch octagonal prestressed concrete. These vertical piles did not have stingers. Piles S2.1 and T2.1 were 62 ft long, R2.1 was 67 ft long. Near the pile top the cross-sectional area was reduced to 214 square inches due to dowel holes. Below the dowel holes the nominal cross-sectional area was 225 square inches.

Pile T4.4 was a 16.5 inch octagonal pile with an 8 ft HP stinger and a total length of 68 ft. We made a P.I.T. test on T4.4 and on the pile immediately east of T4.4; both piles were battered. Pile CC7.1 was a battered 18 inch octagonal pile with an 8 ft stinger and a total length of 68 ft.

Available information indicated that the required axial capacities were 300 kips in compression and 60 kips in tension.

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FIELD RESULTS

Tables 1 and 2 summarize field results for PDA tests on R2.1 and S2.1. Tabulated quantities include tip elevation, blow count, blow rate, computed ram stroke, average energy transfer, measured driving stresses and computed bearing capacity.

The PDA test on CC7.1 indicated severe pile damage 53 ft below the pile top. This damage is apparent in the measured force and velocity records shown in Figure 1. The computed integrity factor, "beta", was 55; this value is equated to a prediction of severe damage.

DISCUSSION OF RESULTS

Pile Stresses

Excluding the restrikes the highest tabulated driving stress was 3.3 and occurred near tip elevation -43 ft on S2.1 This peak compressive stress is consistent with results from prior tests, and is well below the recommended 4.75 ksi upper limit. The peak computed tension stress was 1.2 ksi, and compared favorably with the recommended 1.4 ksi upper limit.

The recorded driving stresses indicate that routine axial driving should not cause pile damage. However, improper hammer-pile alignment or subsurface obstructions will increase local pile stresses. Thus, we recommend that proper alignment be carefully maintained during all driving and that blow count records be reviewed for evidence of subsurface obstructions. When blow counts are low during the start of driving tension stresses will increase as the stroke increases. Thus, we recommend continued use of the Saximeter to monitor the hammer's blow rate and stroke.

Hammer Energy Transfer

Energy transfer near the end of driving on S2.1 ranged from 14 to 16 kip-ft. These values indicate hammer performance that is consistent with prior PDA monitoring.

Bearing Capacity

Bearing capacities were computed with the Case Method and CAPWAP. Tables 1 and 2 present the field Case Method results which were calculated according to the RMX equation with a damping factor J=0.69.

Installation driving on S2.1 ended with a blow count of 36 BPF (18/.5 ft) and a computed axial compressive capacity of 300 kips. This computed capacity reflects resistance during driving. Time dependant soil may increase the friction and total resistance of S2.1.

Pile R2.1 was tested in restrike, approximately 24 hours after installation. The final installation blow count was 6 BPF. The restrike blow count was 30 BPF based on the blows for the first two inches. The computed Case Method capacity, based on early restrike blows, was 270 kips.

To confirm the Case Method capacity and compute the magnitude of the skin friction we completed a CAPWAP analysis of the fourth blow of the restrike. Appendix B contains detailed CAPWAPC output. The total CAPWAP capacity was 280 kips with 126 kips of shaft friction and 154 kips of end bearing. Note that R2.1 did not have a stinger.

Pile Integrity Tests (P.I.T.)

P.I.T. records for T2.1, S2.1, R2.1, T4.1 and the reference pile for T4.1 appear in Appendix C. The records are presented as plots of averaged pile top velocity and averaged acceleration. The plotted velocity, which is the basis for our integrity evaluations, is obtained from the acceleration by numerical integration.

The P.I.T. records for T21., S2.1 and R2.1 indicate very similar pile-top motion in response to the hammer impact. Friction resistance concentrated over the lower 5 to 10 ft of each pile appeared to cause an upward traveling compressive wave. This wave was then followed by clear tensile reflections

from each pile's end. In all three cases the reflection times correspond to the correct nominal pile lengths. Based on prior and current results the low strain wave speed for analysis of these P.I.T. records was 14100 to 14200 ft per second. (Wave speeds computed with P.I.T. are commonly higher than those computed from PDA data. This difference is attributed to the differing strain levels in these tests and the concrete's non-linear stress-strain behavior.)

Based on the P.I.T. records of T2.1 and R2.1 our field conclusion was that both piles were sound to within approximately 7 ft from the pile toe and were most likely sound over their entire length. The ambiguity at reflections lengths of 7 ft above the toe was noted but was attributed to effects of soil response. The original concern for R2.1 was that tensile driving stresses may have caused pile damage. High tensile stress and tensile damage would not generally occur close to the pile toe.

Later testing on S2.1 yielded P.I.T. records very similar to the R2.1 and T2.1. The similarity between the three records strengthened the conclusion that all pile's appeared sound over their entire lengths. PDA tests on R2.1 and S2.1 confirm our conclusion that piles tested on November 27 were undamaged.

Based on P.I.T. tests on T4.4 and an adjacent pile we concluded that T4.4 had a significant reduction in cross-sectional stiffness approximately 8 to 9 ft below the pile top. Although this pile had visible longitudinal cracks and spall zones above the water line we concluded that the degree of damage increased 8 to 9 ft from the top.

DISCUSSION OF RESULTS

Results from the testing conducted for this report can be summarized as follows:

1. Pile R2.1, S2.1 and T2.1 were not damaged at the time of testing. This conclusion was first based on P.I.T. results for T2.1 and R2.1 and later confirmed with PDA monitoring on S2.1 and R2.1, and a P.I.T. test on S2.1.

December 6, 1990

2. The Case Method capacity of S2.1 at the end of installation was 300 kips. CAPWAP analysis of a restrike on R2.1 yielded a total capacity of 280 kips with 126 kips of skin friction. Because R2.1 was restruck only one day after installation, we expect continued soil setup on this pile. This conclusion is based on previous experience at this site.

3. P.I.T. results for T4.4 indicated an increase in the level of pile damage approximately 8 to 9 ft below the pile top. This damage is in addition to the damage visible above the water line.

4. The restrike of CC7.1 indicated severe pile damage approximately 53 ft below the pile top (50 ft from our gages).

It was a pleasure to work with you on this project. We hope that you will contact us if you or your client have any questions about this report.

Sincerely,

GOBLE RAUSCHE LIKINS
AND ASSOCIATES, INC.

Robert F. Miner

RFM:cp
grlwa1290

Table 1. Summary of Results from the Pile Driving Analyzer
Coleman Ferry Terminal, Seattle, Washington
Pile: S-2.1, 16.5 inch Octogonal, No Stinger

Approx. Tip Elev.	Penetration Resistance	Average Maximum Transfer Energy	Computed Ram Stroke	Computed Maximun Tensile Stress	Computed Maximun Compressive Stress	Case Method Capacity RMX J= 0.69
(a) ft	(a) blow/ft	kip/ft	(b) ft	(c) ksi	(c) ksi	kips
Installation: November 27, 1990, Fuel Setting No. 2.						
-36	18	14		0.8	2.6	230
-39	14	13		1.0	2.7	200
-43	27	16	7.2	1.2	3.3	300
-46	18 blow/.5"	15	7.1	1.1	3.1	300

(a) Penetration and blow count data provided by the State of Washington.
(b) The approximate ram Stroke was computed from the hammer blow rate.
(c) Computed stresses do not include bending stresses or prestress.

Table 2. Summary of Results from the Pile Driving Analyzer
Coleman Ferry Terminal, Seattle, Washington
Pile: R-2.1, 16.5 inch Octogonal, No Stinger

Approx. Tip Elev.	Penetration Resistance	Average Maximum Transfer Energy	Computed Ram Stroke	Computed Maximun Tensile Stress	Computed Maximun Compressive Stress	Case Method Capacity RMX J= 0.69
(a) ft	(a) blow/ft	kip/ft	(b) ft	(c) ksi	(c) ksi	kips
Restrike: November 27, 1990, Fuel Setting No. 2.						
-52	5 blow/2"	15			3.5	270

(a) Penetration and blow count data provided by the State of Washington.
(b) The approximate ram Stroke was computed from the hammer blow rate.
(c) Computed stresses do not include bending stresses or prestress.

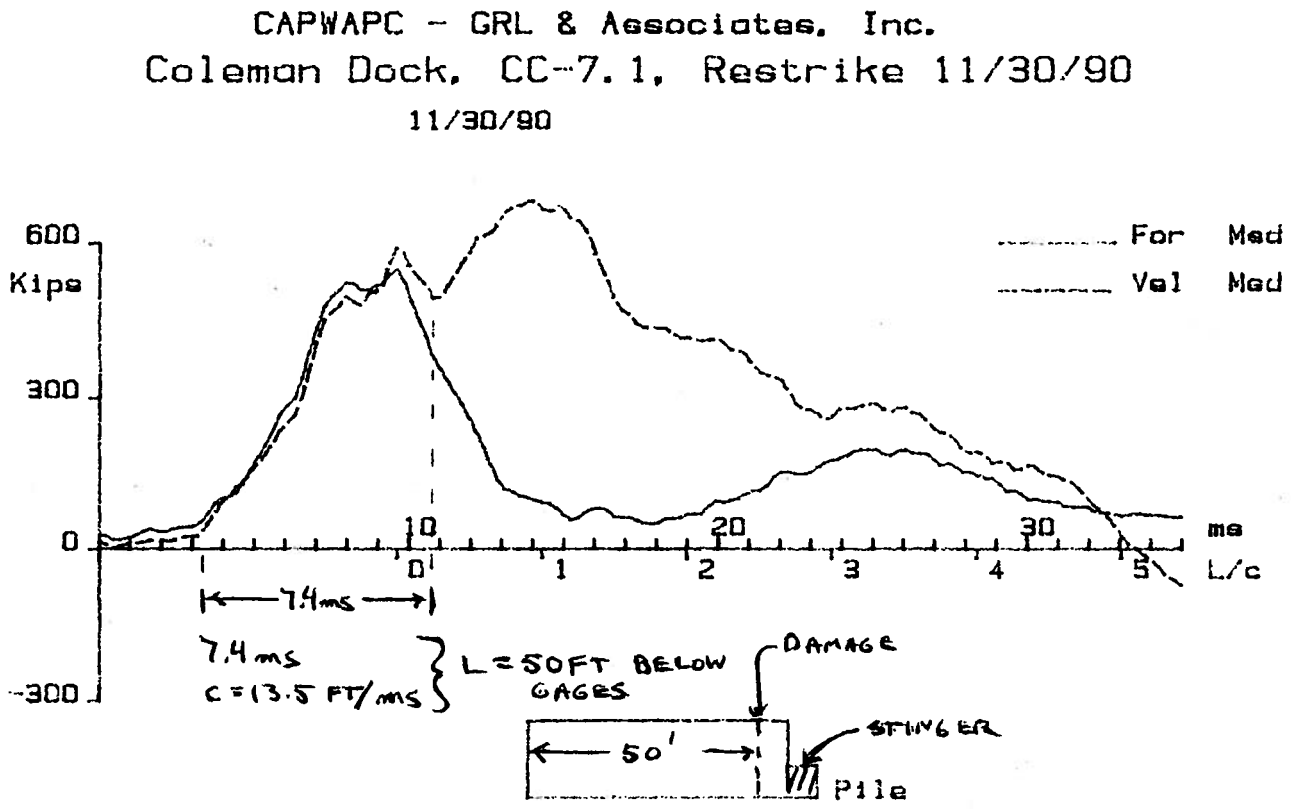


Figure 1: Dynamic Measurements of Force and Velocity for CC-7.1.

APPENDIX B

CAPWAPC Results

R2.1

Final CAPWAPC Capacity: Ru 280.0, Skin 126.4, Toe 153.5 Kips

Soil Sgmnt No.	Depth Below Gages ft	Depth Below Grade ft	Ru Kips	Sum of Ru Up Kips	Sum of Ru Down Kips	Unit Resist. w. Respect to Depth Kips/ft	Unit Resist. w. Respect to Area Kips/f2	Smith Damping s/ft	Quake inch
				280.0					
1	50.5	9.5	23.3	256.7	23.3	3.45	.75	.071	.080
2	57.3	16.3	39.1	217.6	62.4	5.80	1.26	.071	.080
3	64.0	23.0	64.1	153.5	126.4	9.51	2.07	.071	.080
Average Skin Values			42.1			5.50	1.36	.071	.080
Toe			153.5				98.23	.092	.595

Soil Model Parameters/Extensions		Skin	Toe
Case Damping		.096	.152
Unloading Quake	(% of loading quake)	60	100
Unloading Level	(% of Ru)	83	
Resistance Gap	(inch)		.02

CAPWAPC - GRL & Associates, Inc.
Coleman Dock, Restrike R2.1, 11/27/90 11/28/90

EXTREMA TABLE

Pile Sgmnt No.	Depth below Gages ft	max. Force Kips	min. Force Kips	max. Comp. Stress Kips/in2	max. Tension Stress Kips/in2	max. trnsfd. Energy Kips-ft	max. Veloc. ft/s	max. Displ. in
1	3.4	700.3	-23.2	3.18	-.11	22.20	7.3	.867
2	6.7	715.6	-42.2	3.18	-.19	22.66	7.1	.860
3	10.1	715.7	-58.2	3.18	-.26	22.63	7.1	.850
5	16.8	712.2	-102.2	3.17	-.45	22.49	7.1	.840
7	23.6	716.4	-85.4	3.18	-.38	22.27	7.1	.820
9	30.3	716.1	-68.3	3.18	-.30	22.00	7.1	.800
11	37.1	722.9	-28.4	3.21	-.13	21.75	7.3	.790
13	43.8	676.2	-31.7	3.01	-.14	21.69	8.0	.780
15	50.5	592.5	-35.9	2.63	-.16	21.64	9.2	.770
17	57.3	480.0	-21.3	2.13	-.09	19.60	9.3	.760
18	60.6	361.9	-.1	1.61	.00	16.27	9.8	.760
19	64.0	326.5	.0	1.45	.00	10.80	10.1	.759
Absolute	37.1			3.21		(T=	25.3 ms)	
	16.8				-.45	(T=	30.7 ms)	

PILE PROFILE AND PILE MODEL

	Depth ft	Area in2	E-Modulus Kips/in2	Spec. Weight Kips/ft3	Circumf. ft
1	.00	214.00	6075.5	.150	4.600
2	1.50	214.00	6075.5	.150	4.600
3	1.50	225.00	6075.5	.150	4.600
4	64.00	225.00	6075.5	.150	4.600

Toe Area (ft2) 1.563

Segmnt No.	Depth B.G. feet	Impedance Kips/ft/s	Imp. Change %	T. Slack inch	C. Slack inch	Circumf. feet
1	3.37	97.60	.00	.000	.000	4.600
2	6.74	99.77	.00	.000	.000	4.600
17	57.26	99.77	.00	.000	.000	4.600
19	64.00	99.77	.00	.000	.000	4.600

Pile Damping (%) 2.0, Time Incr (ms) .246, Wave Speed (ft/s) 13701.0

Coleman Dock, Restrike R2.1, 11/27/90

Case Method Capacity Results

	J=0.0	J=0.1	J=0.2	J=0.3	J=0.4	J=0.5	J=0.6	J=0.7	J=0.8	J=0.9
Rs	369.	281.	194.	106.	19.	0.	0.	0.	0.	0.
Rx	380.	357.	334.	311.	300.	291.	283.	276.	270.	264.
Ru	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Ra Ra2	228.	213.								

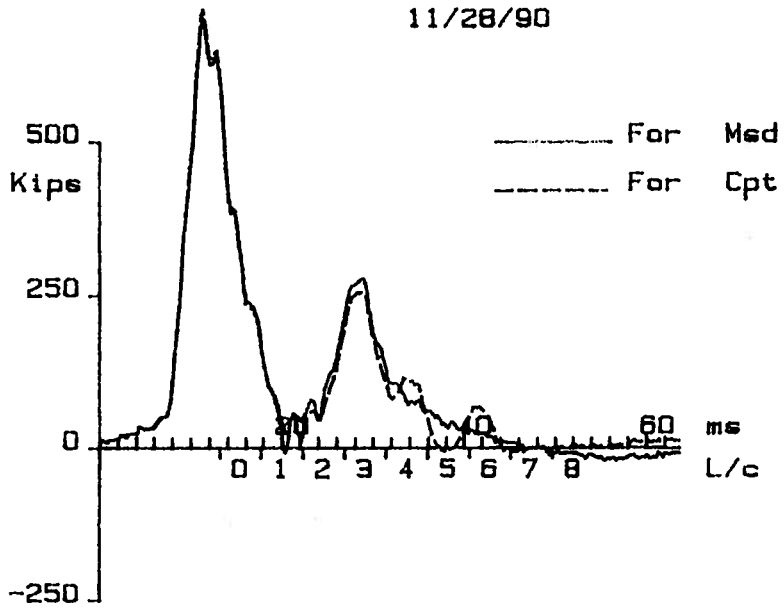
Current CAPWAPC Ru = 280.0; Corresponding J(Rs) = .10; J(Rx) = .64

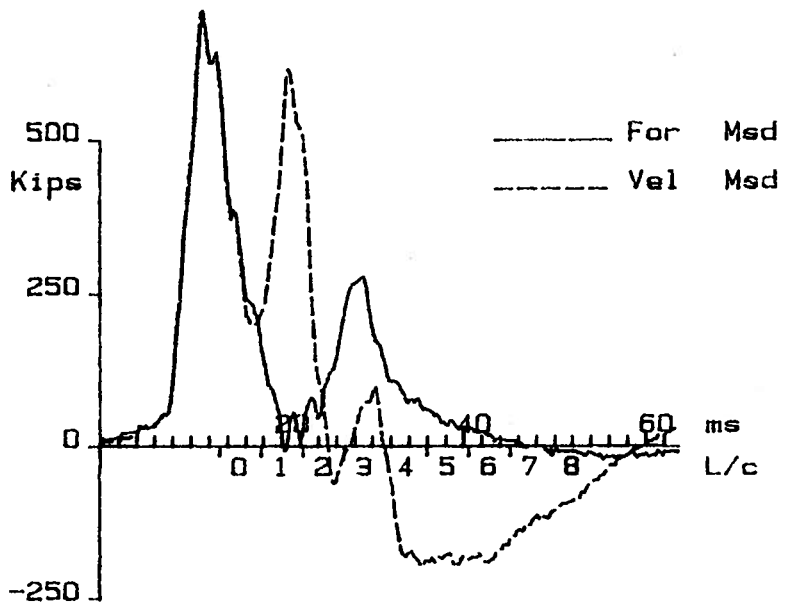
VMAX	VFIN	V1*Z	F1	FMAX	DMAX	DFIN	EMAX	EFIN	R EX	R EF
7.29	.34	590.1	614.9	700.3	.867	.450	22.2	21.2	420.6	635.7

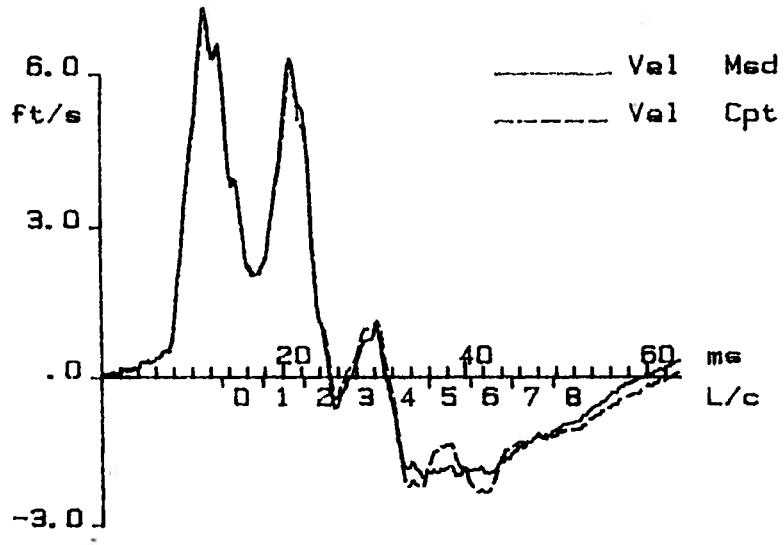
CAPWAPC - GRL & Associates, Inc.

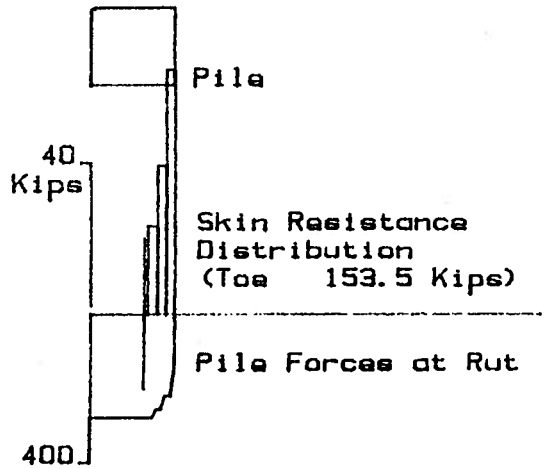
Coleman Dock, Restrike R2.1, 11/27/90

11/28/90









CAPWAPC - GRL & Associates, Inc.

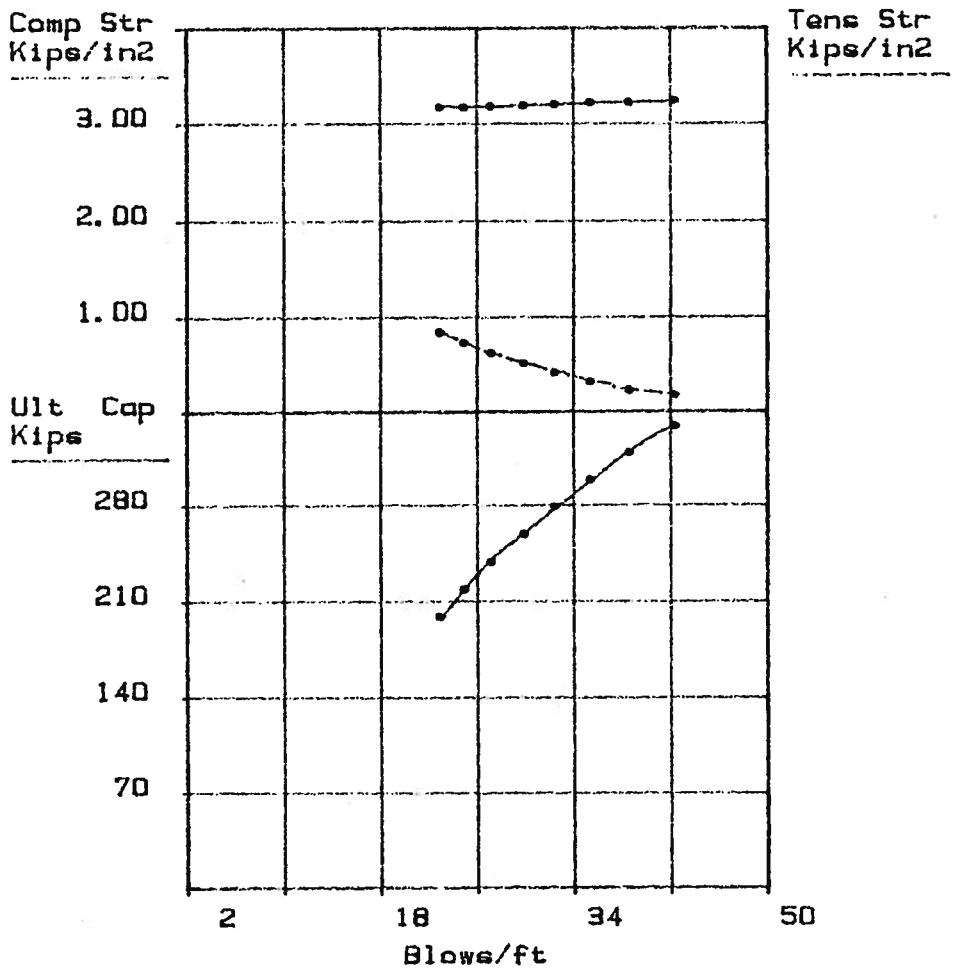
CAP-WEAP RESULTS

Coleman Dock, Restrike R2.1, 11/27/90

I	Ru(act) Kips	Blct Bl/ft	ENTHRU Kips-ft	S max Kips/in2	S min Kips/in2
1	200.0	21.8	20.6	3.181	-.852
2	220.0	23.9	21.3	3.181	-.742
3	240.0	26.2	21.8	3.194	-.632
4	260.0	29.0	22.2	3.206	-.529
5	280.0	31.7	22.5	3.219	-.426
6	300.0	34.8	22.6	3.232	-.329
7	320.0	38.1	22.8	3.239	-.239
8	340.0	42.0	22.9	3.252	-.187

CAPWAPC - GRL & Associates, Inc.

Coleman Dock, Restrike R2.1, 11/27/90 11/28/90



APPENDIX C

Pile Integrity Test (P.I.T.) Results

R2.1
S2.1
T2.1
T4.4
Reference T4

GRL & Associates: Pile Integrity - PIT

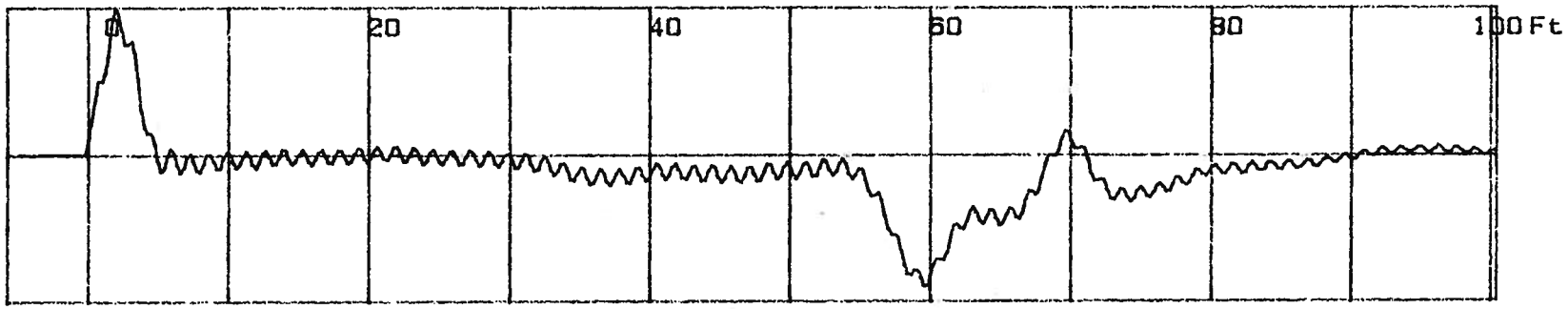
Project: Coleman
Loc:
Date: 11/27/90

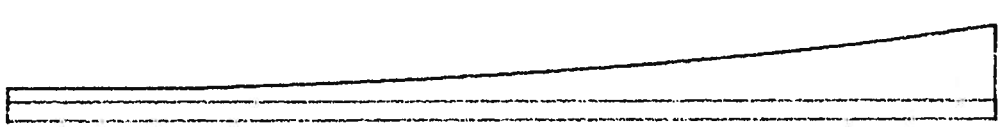
Pile: R2.1
Test A
Avgd 10 Bls

1.50 Ms

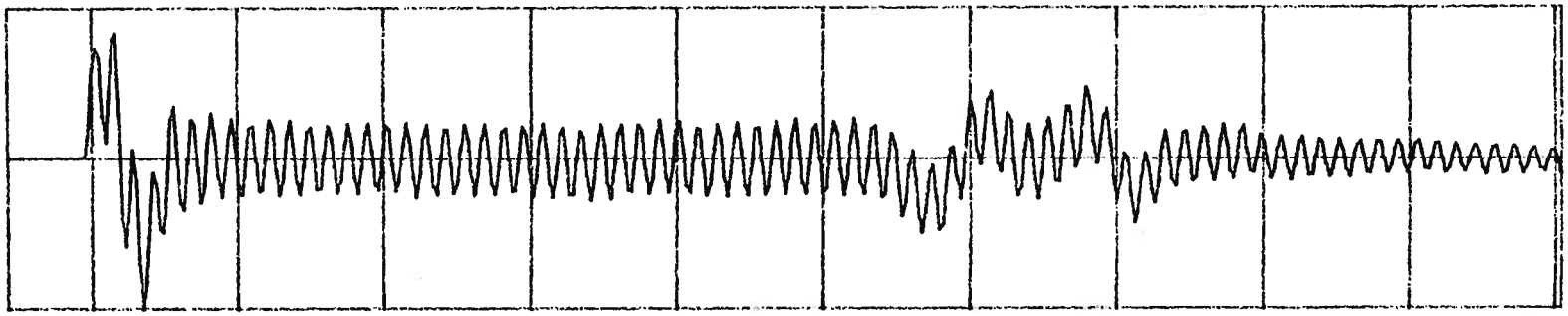
1 2 3 4 5 6 7 8 10 11

Vel-Avg-Ampd





Acc-Avg-Ampd



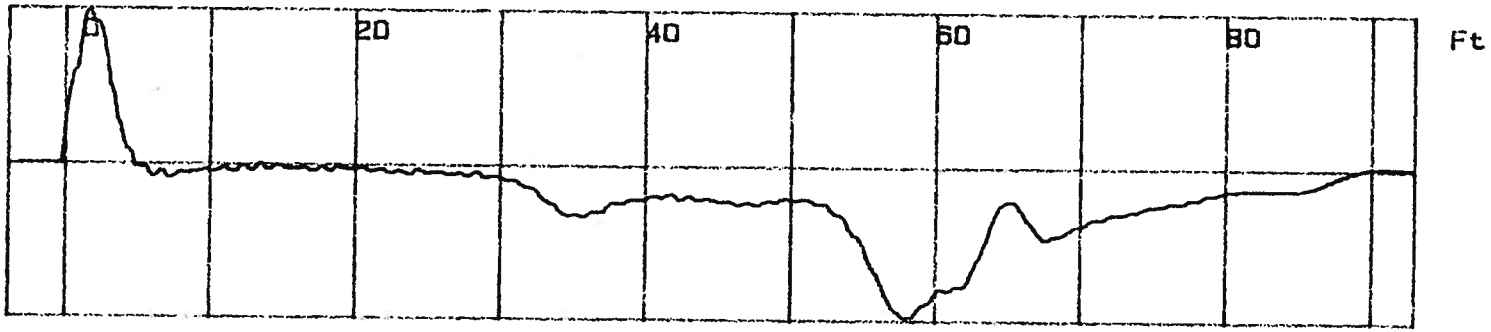
GRL & Associates: Pile Integrity - PIT

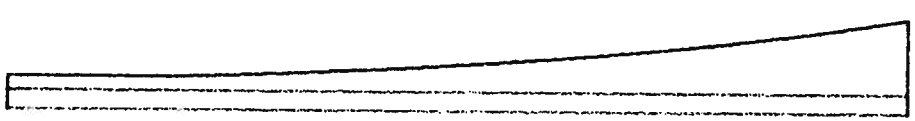
Project: Coleman Pile: S2.1
Loc:
Date: 11/27/90 Avgd 19 Bls

1.50 Ms

1 2 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Vel-Avg-Ampd



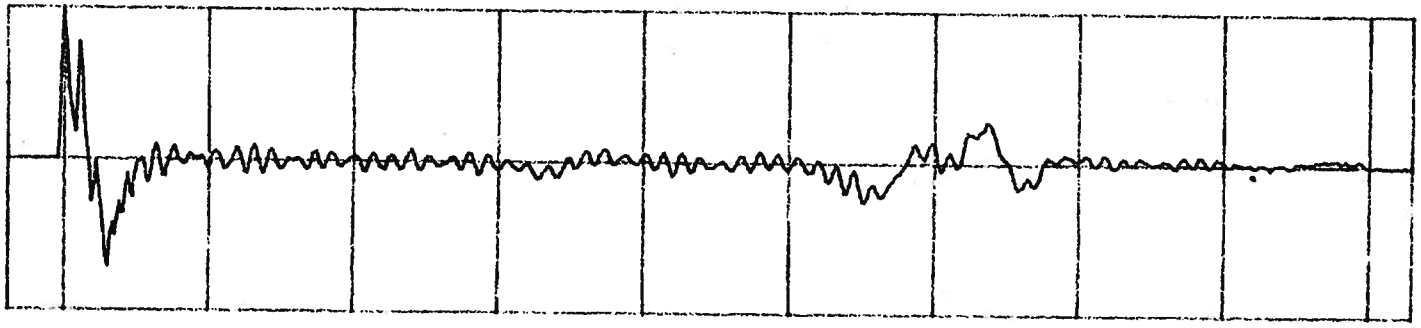


5.0

62.00 Ft

14.20 Ft/ms

Acc-Avg-Ampd



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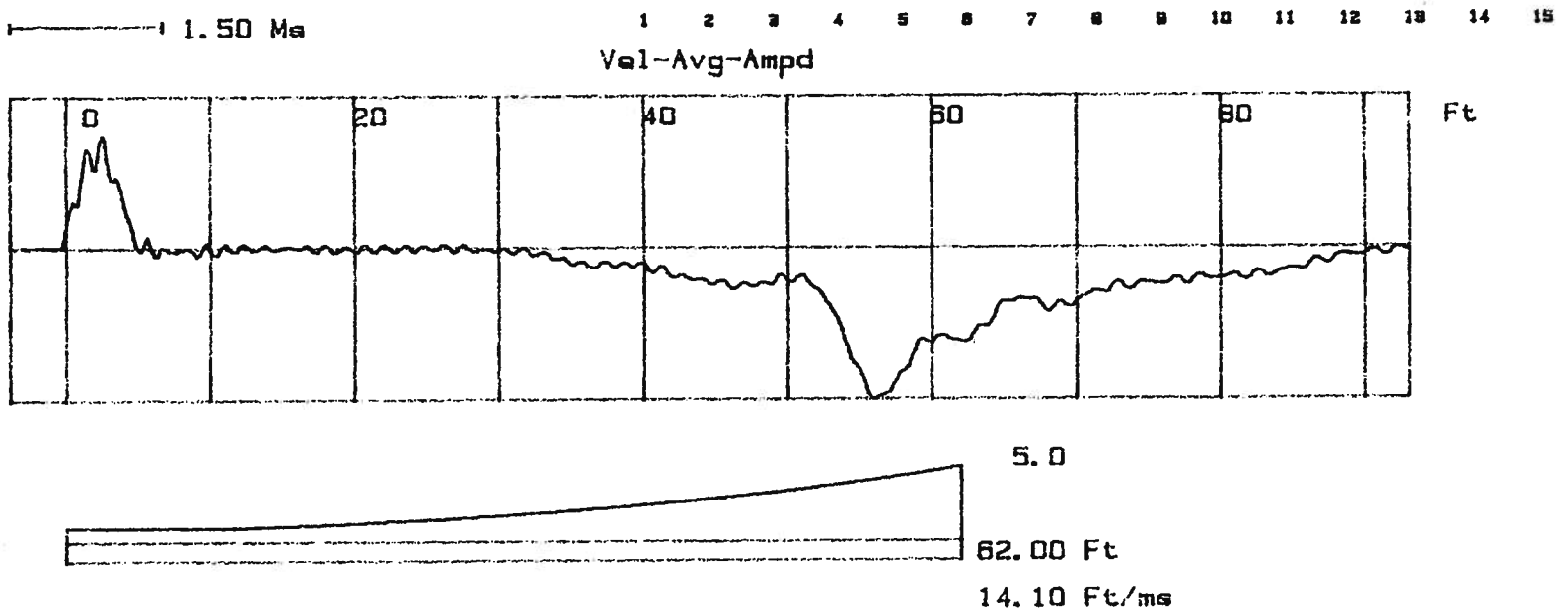
CRL & Associates: Pile Integrity - PIT

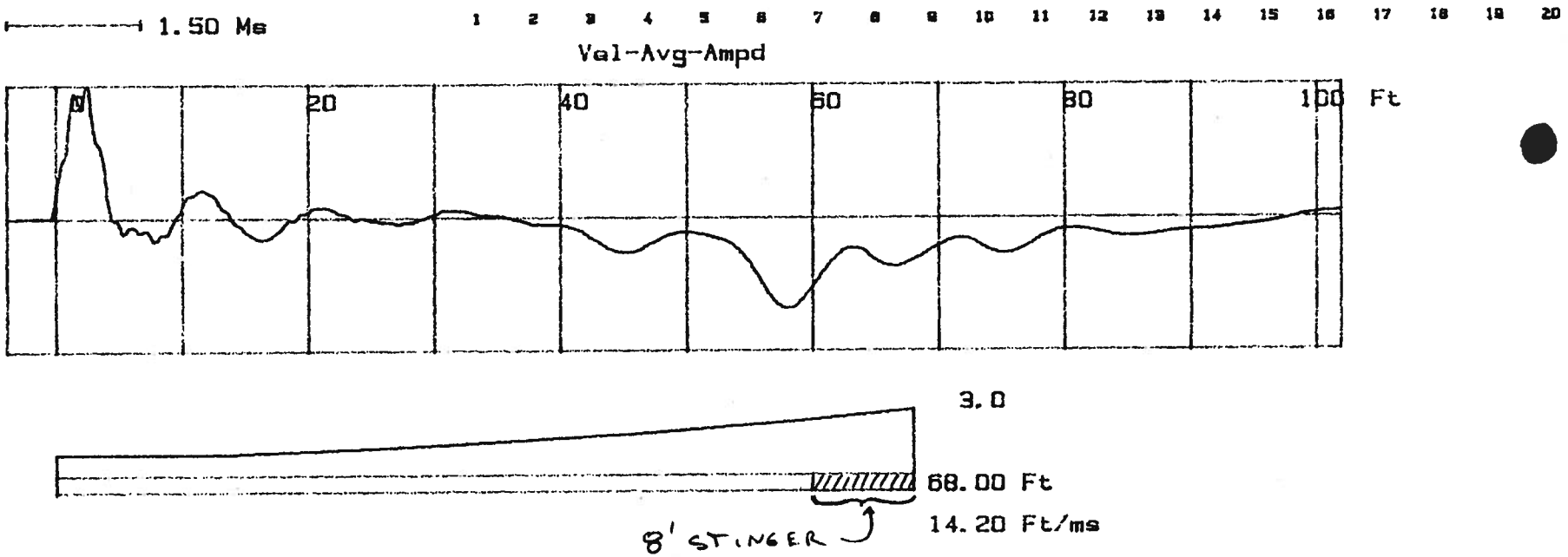
Project: Coleman Pile: T2.1
Loc:
Date: 11/27/90 Avgd 15 Bls



GRL & Associates: Pile Integrity - PIT

Project: Coleman
Loc: SW 16.5"
Date: 11/30/90

Pile: T-4.4
8' sting
Avgd 20 Bls



GRL & Associates: Pile Integrity - PIT

Project: Coleman
Loc: SE 16.5"
Date: 11/30/90

Pile: T-4 Refn
8' sting
Avgd 15 Bls